CCD Astrometric Measurements of WDS 04155+0611

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Abstract: Twenty-two separations and position angle astrometric measurements were made of the multiple star system WDS 04155+0611. This system includes the pairs STTA 45 AB, H 6 98 AC, H 6 98 CD, and STU 18 CE. All measurements were compared with historical measurements from the Washington Double Star Catalog. Our astrometric results compare favorably with other recent observations.

Introduction

The Army and Navy Academy (ANA) is a college preparatory middle and high school with a military structure focused on personal growth and leadership. The ANA Astronomy Club is one of the newest and most active clubs on campus that has grown from an observational club to a group of active student astronomical researchers.

In the Fall of 2014, ANA acquired new astronomical equipment through a generous grant from the McMahan Foundation, enabling new research capabilities. Our team's research project focused on: 1) astrometric analysis of binary stars and 2) calibration of the new telescope system against professional grade equipment. The student members of the team are shown in Figure 1.

Figure 1: Left to Right: Zhiyao Li, Zhixin Cao, Steve Qu, and Jeff Li

The Army and Navy Academy is located on a beach in Carlsbad, CA. Due to this location, there are many nights that the sky is obscured by fog and coastal clouds. As a result, we were not able to make the observations necessary to address our second objective and used the global iTelescope network to perform astrometric analysis using MaximDL and Mirametrics Mira Pro x64. The research and CCD imaging focused on the multiple star system WDS 04155+0611 (Figure 2), including the components STTA 45 AB, H 6 98 AC, H 6 98 CD, and STU 18 CE.

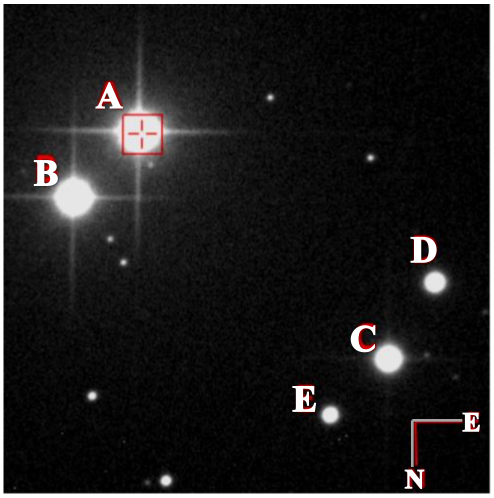

Figure 2: WDS 04155+0611 with the A component marked by a square in Mira Pro x64. The camera's orientation relative to celestial north is indicated at the lower right.

Equipment and Procedures

The T3 and T11 telescope/camera combinations were selected from the iTelescope network which is located at an elevation of 7,500 feet in New Mexico. These two systems allowed comparative observations to enhance the credibility of the final measurements.

The T3 telescope is a Takahashi TOA-150mm refractor with a 1095mm focal length mounted on a Paramount GTS. A one-shot color SBIG ST-8300C yielded a resolution of 1.02″/pixel with a field of view of 42.4 x 56.3′. The images obtained from the T3 were taken on March 5th, 2015 at an exposure time of 180 seconds.

The T11 telescope is a Planewave 20" CDK with a 2280mm focal length through a 0.66 focal reducer, mounted on a Planewave Ascension 200HR mount. An FLI ProLine PL11002M camera yielded a resolution of 0.81″/pixel with a field of view of 36.2 x 54.3′. Observations with an Astrodon red filter were performed on March 10th and March 27th, 2015. Observations with a hydrogen alpha filter were performed on March 27, 2015. Exposure times were 180 seconds for each image.

Once the images were acquired by the T3 and T11, iTelescope pre-processed the images using the appropriate darks and flats. We utilized MaximDL v6 to perform astrometric calibrations and insert World Coordinate System (WCS) positions into the FITS header. MaximDL located a number of stars in the CCD image, and then matched them to the Fourth U.S. Naval Observatory CCD Astrograph Catalog (UCAC4). The astrometric calibration data for each image is outlined in Table 1.

WDS	Tel.	Date	Filter	# UCAC4 Stars	RA/DEC	Camera Angle, Focal Length, Plate Scale
04155+0611	T3	3/5/2015	Color	221 of 1216	RA 04h 15m 28.8s, Dec +06° 11' 10.3"	+04° 06.7', FL 1104.8 mm, 1.01"/Pixel
	T11	3/10/2015	Red	420 of 1030	RA 04h 15m 28.8s, Dec +06° 11' 13.2"	+270° 32.2', FL 2265.3 mm, 0.82"/Pixel
	T11	3/27/2015	Red	417 of 1030	RA 04h 15m 28.5s, Dec +06° 11' 06.0"	+270° 13.3', FL 2269.6 mm, 0.82"/Pixel
	T11	3/27/2015	Ha	84 of 120	RA 04h 15m 28.6s, Dec +06° 11' 08.1"	+270° 13.1', FL 2265.7 mm, 0.82"/Pixel
	T11	3/27/2015	Red	415 of 1030	RA 04h 15m 28.7s, Dec +06° 11' 08.5"	+270° 14.3', FL 2269.0 mm, 0.82"/Pixel
	T11	3/27/2015	Ha	37 of 120	RA 04h 15m 28.7s, Dec +06° 11' 09.8"	+270° 13.5', FL 2263.1 mm, 0.82"/Pixel

Table 1: MaximDL astrometric calibration data for the T3 and T11 telescopes.

We then used Mirametrics Mira x64 Pro to get accurate separations and position angles of each double star. Figure 3 shows the signal per pixel acquired by Mira x64 Pro. Figure 4 shows the signal level and saturation of the A and B components of the system.

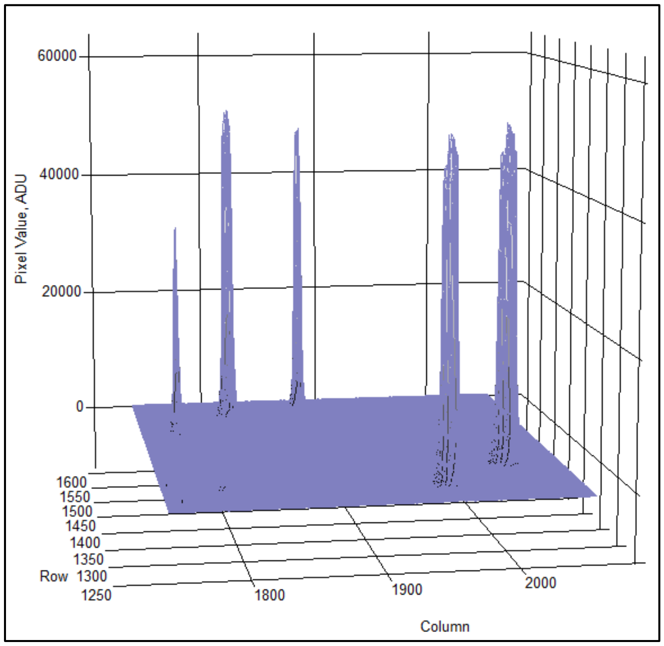

Figure 3: The pixel value in ADU vs. position on the CCD image.

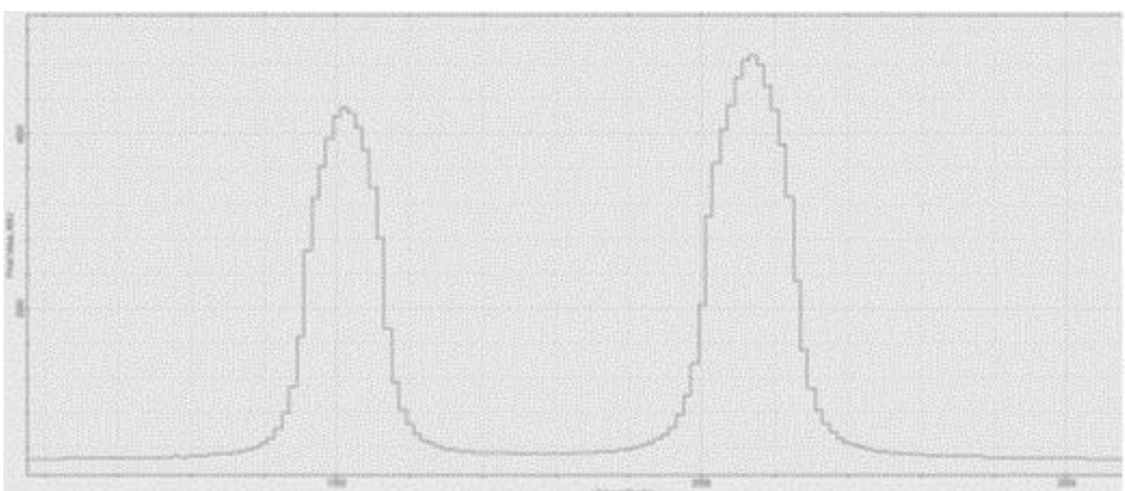

Figure 4: Graphical representation of the signal and saturation of the A and B stars.

Having identified the components STTA 45 AB, H 6 98 AC, H 6 98 CD, and STU 18 CE in the WDS 04155+0611 system, each combination was measured for position angle and separation. Mira Pro x64 locates the centroid of each star being measured and uses its right ascension and declination to calculate the position angle and separation between the stars. Figure 5 shows the measurements of H 6 98 AC. Microsoft Excel was then used to calculate the standard deviations and standard errors of mean from the astrometric results (Frey et al. 2010).

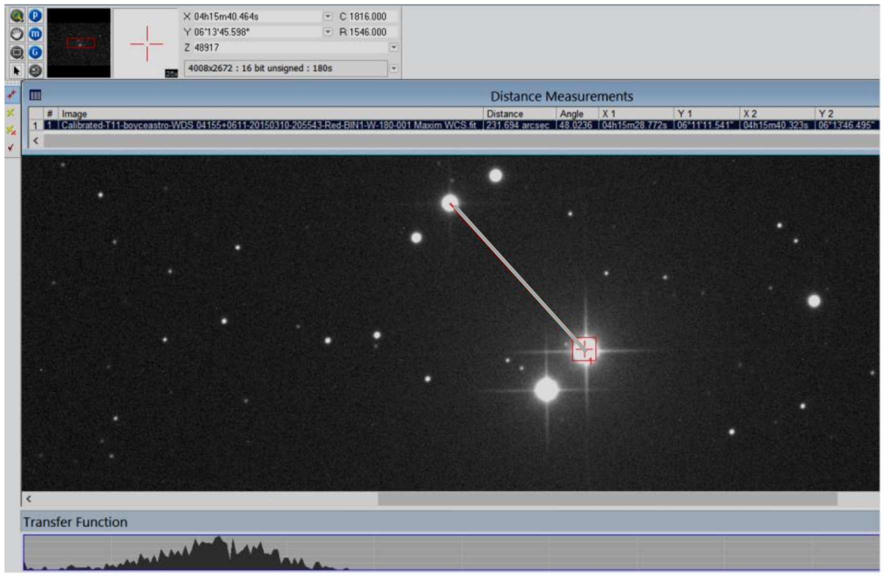

Figure 5: Measurement of H 6 98 AC in Mira Pro x64.

Results and Discussion

Table 2 shows the observational results of each pair in the WDS 04155+0611 system, including the separation, position angle, standard deviation, and standard error of the mean.

	Sep.	St. Dev.	St. Err.	P.A.	St. Dev.	St. Err.
STTA 45 AB	64.30”	0.44”	0.073”	315.58°	0.73°	0.122°
H 6 98 AC	233.01”	0.86”	0.143”	48.09°	0.05°	0.008°
H 6 98 CD	55.82”	0.18”	0.031”	314.55°	0.16°	0.026°
STU 18 CE	61.91”	0.14”	0.024”	149.28°	0.21°	0.035°

Table 2: Separation and position angle measurements with their standard deviations and standard errors of mean for all pairs of the WDS 04155+0611 system.

The standard deviation of the separations of pairs CD and CE are smaller than pairs AB and AC. The AC separation standard deviation is small, however, when compared to the total separation (0.86"/233.01" or 0.36%). This pair's wide separation enables a very accurate position angle measurement for AC with a small standard deviation (0.05°). The relative brightness of the A and B stars may have introduced variation in the centroid approximation computed by the software, which may account for the greater separation and position angle standard deviations for the AB pair.

The measurements of the AC, CD, and CE pairs with the T-3 telescope have greater position angle and separation deviations than those obtained by the T11 telescope. Aside from the lower resolution provided by the 150mm T3 telescope, one other possible explanation for these greater deviations is that the T3 telescope uses a Bayer Matrix over each pixel in order to obtain a one-shot color image rather than a single filter such as the Astrodon red and hydrogen alpha in the T11 telescope. One may also note a greater consistency in the T11 measurements with the hydrogen alpha filter compared to the Astrodon red filter, especially for the AB and AC pairs.

Table 3 shows the results of the present study compared to those published in the Washington Double Star Catalog (WDS). For each pair, the first and last measurements are given with our 2015 data to the right. The results are consistent with recent observations.

Pair	Obs. History			Separation (″)			Position Angle (°)		
	#	First	Last	First	Last	2015	First	Last	2015
STTA 45 AB	37	1875	2012	65.47	64	64.3	314.8	315.9	315.069
H 6 98 AC	13	1885	2011	213.3	234.42	233.01	47.4	47.7	48.09
H 6 98 CD	11	1897	2012	51.669	55.63	55.82	317.5	314.6	314.55
STU 18 CE	9	1961	2012	57.249	61.39	61.91	144.8	149.4	149.28

Table 3: Measurements from the present study compared to WDS measurements.

The C component appears to be moving away from the AB pair at a faster rate than the AB pair's relative motion. The AB pair in Figure 6 displays limited motion over the past 140 years. A closer analysis will reveal that the upper and lower data points for B in Figure 6 are only from two disparate measures in the 1980s. All other 35 measurements cluster closely around the middle point for B in Figure 6. The AC pair however shows substantially greater relative motion, with C moving away from A. Figure 7 depicts this motion over the past 130 years with a linear trend line.

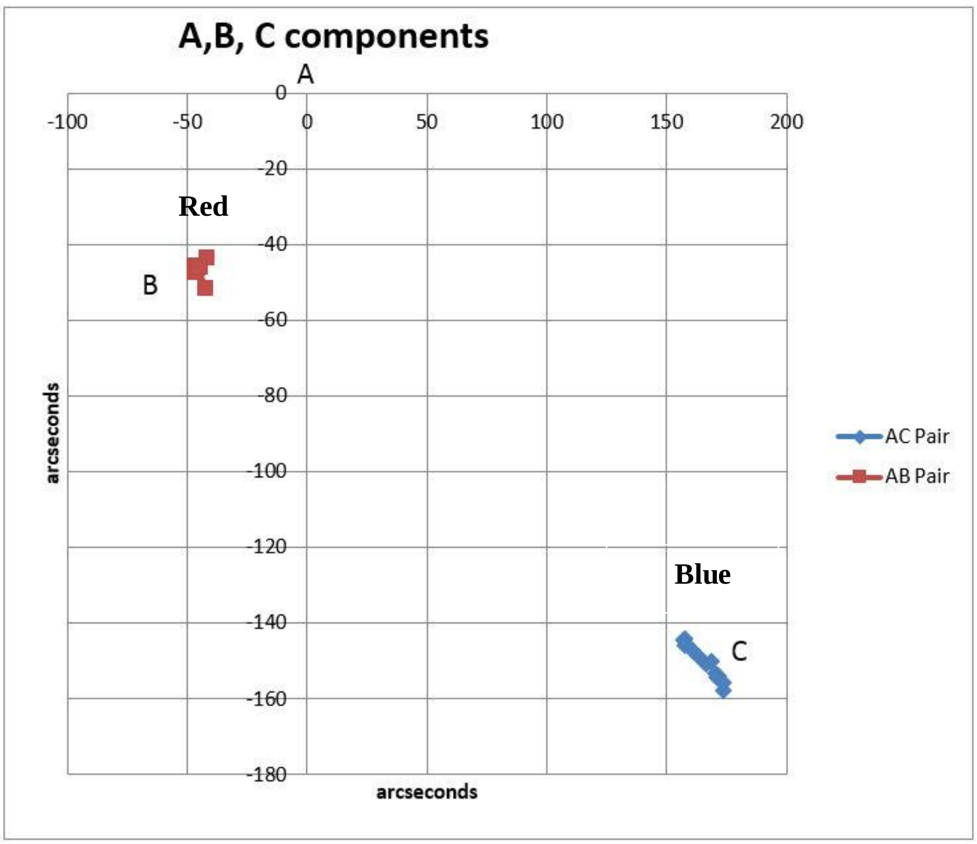

Figure 6: B and C component movement relative to A.

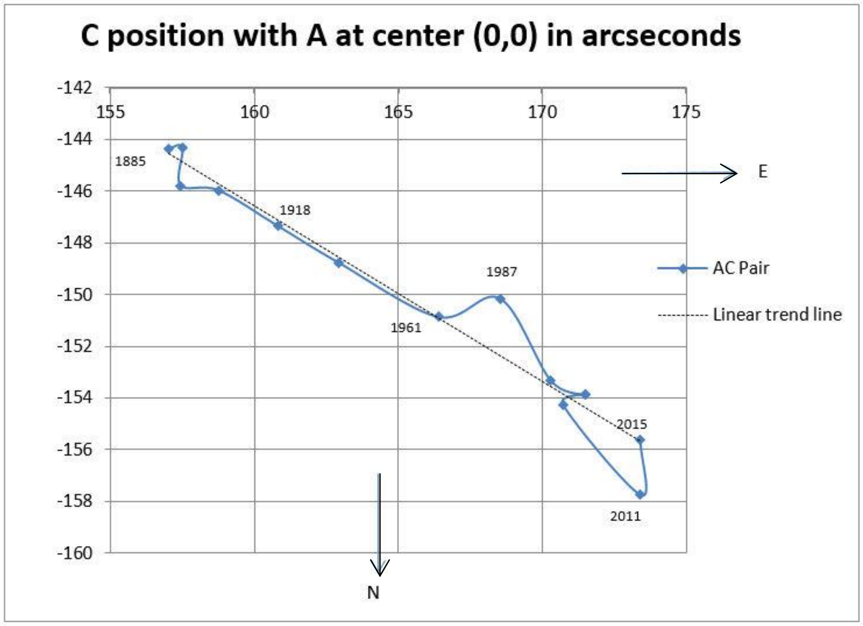

Figure 7: C movement relative to A.

Figure 8 shows the motions of D and E relative to C. There is slightly more consistent apparent motion of the E component relative to C than the D component relative to C.

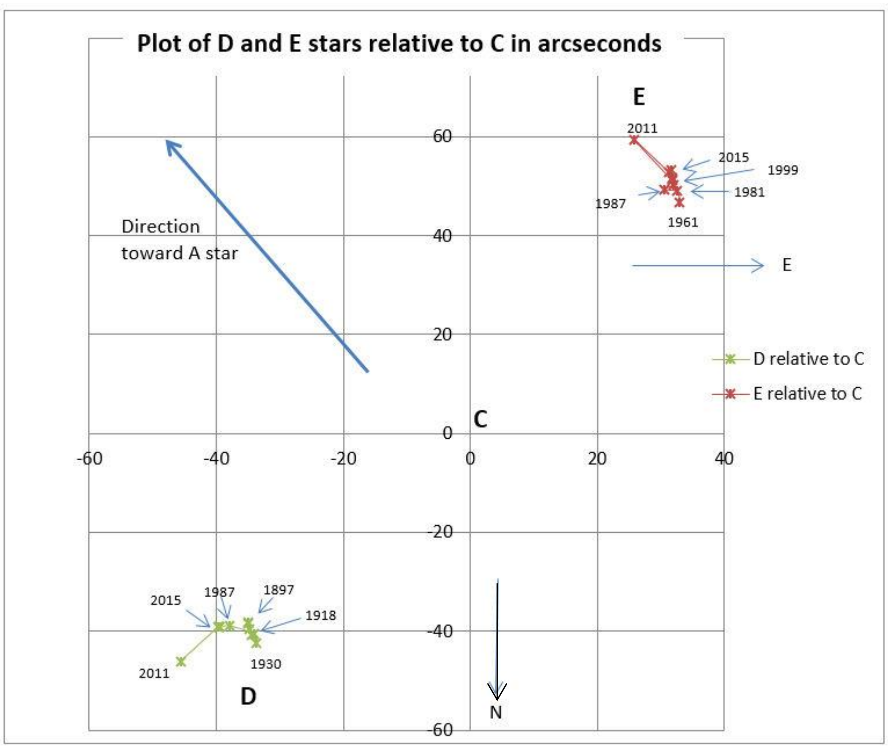

Figure 8: The motions of D and E relative to C.

Conclusions

The motion of the C component relative to A and B appears to be linear. Therefore, it is possible that it is not gravitationally bound to those components. The D and E components show some motion relative to C. Future observations may establish a long term trend in their motion.

Acknowledgements

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